DOCUMENTATION OF DECISION-AIDING SOFTWARE:

RAM FUNCTIONAL DESCRIPTION

DECISIONS AND DESIGNS INC.

Dorothy M. Amey
Phillip H. Feuerwerger
Roy M. Gulick

September 1979

N00014-79-C-0069

ADVANCED DECISION TECHNOLOGY PROGRAM

CYBERNETICS TECHNOLOGY OFFICE
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
Office of Naval Research • Engineering Psychology Programs

DOCUMENTATION OF DECISION-AIDING SOFTWARE:

RAM FUNCTIONAL DESCRIPTION

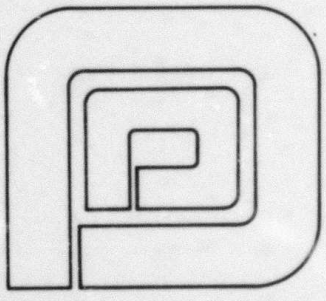
by

Dorothy M. Amey, Phillip H. Feuerwerger, and Roy M. Gulick

Sponsored by

Defense Advanced Research Projects Agency
ARPA Order 3469

September 1979



DECISIONS and DESIGNS, INC.
Suite 600, 8400 Westpark Drive
P.O.Box 907
McLean, Virginia 22101
(703) 821-2828

CONTENTS

CONTENTS (Continued)

FIGURES

RAM: FUNCTIONAL DESCRIPTION

1.0 INTRODUCTION

1.1 Purpose of the Functional Description

This Functional Description provides a technical delineation of the specific functions that the RAM software system must perform. It serves as a formal basis for mutual understanding between the functional designer of the system and the software development personnel. Together with the RAM System Specification, it serves as the basic documentation for systems development and implementation.

1.2 References

1.2.1 Buede, Dennis M., and Peterson, Cameron R. An Application of Cost-Benefit Analysis to the USMC Program Objectives Memorandum (POM). Technical Report TR 77-8-72. McLean, Virginia: Decisions and Designs, Inc., September 1977.

1.2.2 Buede, Dennis M., and Ragland, Janice E. Cost-Benefit Analysis Applied to the Program Objectives Memorandum (POM). Technical Report TR 78-9-72. McLean, Virginia: Decisions and Designs, Inc., November 1978.

1.2.3 Buede, Dennis M. et al. Applications of Decision Analysis to the U.S. Army Affordability Study. Technical Report TR 78-10-72. McLean, Virginia: Decisions and Designs, Inc., December 1978.

1.2.4 Amey, Dorothy M.; Feuerwerger, Phillip H.; and Gulick, Roy M. Documentation of Decision-Aiding Software: RAM Users Manual. McLean, Virginia: Decisions and Designs, Inc., September 1979.

1.2.5 Amey, Dorothy M.; Feuerwerger, Phillip H.; and Gulick, Roy M. Documentation of Decision-Aiding Software: RAM Systems Specification. McLean, Virginia: Decisions and Designs, Inc., September 1979.

1.3 Terms and Abbreviations

1.3.1 RAM - RAM, the name of the system, is an abbreviation for Resource Allocation Model, reflecting the system's major area of applicability.

1.3.2 Terms - Standard mathematical notations and cost-benefit and resource allocation terminology are used throughout this functional description. Cost-benefit and resource allocation terms are defined when they are first encountered. References 1.2.1, 1.2.2, and 1.2.3 provide more detail on the cost-benefit and resource allocation methodology implemented by RAM.

2.0 SYSTEM SUMMARY

2.1 System Description

RAM is a model-building software system that supports the decision process of allocating scarce monetary resources among competing alternatives. Its general purpose is to aid decision makers by providing them with the capability to construct, store, retrieve, exercise, and refine cost-benefit models of the complex resource allocation problems they face.

Cost-benefit analysis serves as the methodological foundation for the RAM system. A RAM model serves as the organizing framework for processing information concerning the costs and relative benefits of the alternatives for resource allocation.

The overall objective of RAM is to prioritize the allocation of resources in a manner that is logically consistent with the decision maker's value structure. For a more complete description of the purpose and use of RAM, see RAM Users Manual, reference 1.2.4.

2.2 Design Objectives

The RAM system is designed to be used interactively by end users who are relatively unsophisticated with respect to computer technology. Accordingly, the design satisfies two human-factors objectives: RAM is a menu-driven system, and one that is generally forgiving of procedural errors made by the user.

In addition, to facilitate the production of the program specification and coding necessary to implement RAM at

a physical site, the system is designed in a hierarchically structured and modular fashion. The logical structure of RAM is contained in RAM Systems Specification, reference 1.2.5.

3.0 DETAILED CHARACTERISTICS

The Resource Allocation Model (RAM) software was developed specifically to serve as a decision aid in the complex and difficult trade-off problem of determining the best procurement mix to be specified in the Program Objectives Memorandum (POM) process of the Department of Defense. RAM aids users in performing cost-benefit trade-offs, and in developing optimal procurement objectives within a fixed budget. It is a highly useful tool for both conventional and zero-base budgeting activities.

The fundamental product of RAM is a resource allocation model. The RAM system enables the user to create, store, retrieve, exercise, and refine resource allocation models interactively.

All of the specific functions that RAM performs are related to the resource allocation model. Therefore, in order to establish a frame of reference for understanding the RAM functions, it is necessary to begin with a detailed description of the format, inputs, and outputs of the resource allocation model. A description of the specific functions that RAM performs appears in Section 4.0.

3.1 Model Description

The RAM model assumes that two or more organizational sponsors (e.g., training, logistics, manpower, etc.) have each proposed several items (e.g., procurement packages, research programs, etc.) for funding. The items all compete with one another for funding consideration. Each item is assumed to have associated costs (spread among several components) and an associated benefit. Both costs and benefit ai . asse A by the item's sponsor group.

The model also assumes that a group of independent judges (honest brokers) has assigned a relative importance weight to one randomly selected item from each sponsor.

Each resource allocation model created by the user has a unique label, and each is constructed using the same generic format. The basic model format is shown graphically in Figure 3-1. The format always consists of all of the following elements which, when completely specified, uniquely define a RAM model.

3.1.1 The problem area - A short label, P, defining the general nature of the resource allocation problem. This label is applied to the model and is used to store and retrieve it.

3.1.2 The organizational sponsors - A list of the n sponsors (S_1, S_2,..., S_n) who collectively have proposed the various items to be funded. Each sponsor is appropriately labeled.

3.1.3 The items - A list of the k items (I_1, I_2,..., I_k) submitted by each sponsor where k varies per sponsor. Each item is appropriately labeled.

3.1.4 Cost components - A list of five cost components (Q_1 through Q_5) describing the different kinds of costs inherent in the total cost associated with each specific item. Each cost category is appropriately labeled. An additional cost component is preassigned the name "other costs."

3.1.5 Item costs - A vector of six separate costs (C_1 through C_6) associated with each item. The first five costs correspond with the five cost components. The sixth cost comprises "all other costs."

PROBLEM AREA

SPONSORS	ITEMS	COSTS Q_1	Q_2	Q_3	Q_4	Q_5	OTHER COSTS	SPONSOR ASSIGNED BENEFITS AND RATIONALE	WEIGHTS
S_1	I_1	C_1	C_2	C_3	C_4	C_5	C_6	B_1, R_1	
	I_2	C_1	C_2	C_3	C_4	C_5	C_6	B_2, R_2	W_1
	I_3	C_1	C_2	C_3	C_4	C_5	C_6	B_3, R_3	
S_2	I_1	C_1	C_2	C_3	C_4	C_5	C_6	B_1, R_1	W_2
	I_2	C_1	C_2	C_3	C_4	C_5	C_6	B_2, R_2	
S_3	I_1	C_1	C_2	C_3	C_4	C_5	C_6	B_1, R_2	W_3
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.

Figure 3-1
RAM MODEL FORMAT

3.1.6 Item benefit - For each item, a sponsor-assigned relative benefit, B_i, such that $0 \leq B_i \leq 100$. The benefit number describes the relative utility that the sponsor attaches to the item. The item having the greatest benefit to each sponsor is always assigned a value of 100.

3.1.7 Rationale - For each sponsor-assigned relative benefit, rationale describing the reasons that the relative benefit was assigned to that item. The rationales are useful for briefing the results and for communicating essential information.

3.1.8 Weights - A vector of weights $(W_1, W_2, \ldots, W_n)$ describing the relative importances of n selected items, one item chosen from each sponsor. The weight assigned to each specific item will be associated with the entire list of items submitted by that sponsor. Note that each sponsor has only one item that will be assigned a weight. Weights are assigned by a group of independent judges.

This completes the model format. The resource allocation model is completely and uniquely specified when the elements described above are defined by the user.

3.2 Results of the Model

The input specifications describing the model can be processed to produce the following results.

3.2.1 Total cost - A single number representing the total cost for each item. The total cost is obtained by adding the cost components C_1 through C_6.

3.2.2 Normalized benefit - A single number, β_{ij}, representing the normalized benefit associated with item j from sponsor i. The normalized benefit indicates the item's

position relative to all items submitted by all of the sponsors. Normalized benefits range on a scale extending from 0 to 100. The normalized benefit is computed as follows.

First, for each sponsor i compute an index of merit, M_i, such that:

$$M_i = \frac{W_i}{B_j}$$

where W_i is the weight previously assigned to the sponsor i's item j by the independent judges, and B_j is the sponsor's original assessment of the benefit of item j.

For example, if the selected item had been assigned an original benefit of 50 by the sponsor but assigned a weight of 10 by the independent judges, then the resultant index of merit is .2.

Second, considering all of the sponsors, determine the value of the greatest index of merit, M_{max}.

Third, compute the normalized benefit, β, of any item j from any sponsor i as follows:

$$\beta_{ij} = \frac{M_i}{M_{max}} \times B_j$$

3.2.3 Cost-benefit ratios - A single number representing the ratio of cost to benefit for each item. This number is calculated by dividing the item's total cost by its normalized benefit. If any specific benefit is equal to zero (and, therefore, the cost-benefit ratio is infinite), the software will automatically yield the maximum representable value for the cost-benefit ratio.

3.2.4 Item rankings - A single list representing the order in which the items should be acquired. The list is arranged according to the cost-benefit criterion (whereby items with the lowest ratio of cost to benefit are bought first). However, items designated as "must-buy" items (designated as such either for political considerations or because of contractual obligations) are always ranked first.

3.2.5 Cost-benefit versus benefit-only display - A set of displays that shows the order in which the items would be bought both according to a cost-benefit criterion (buying in order of smallest to largest cost-benefit ratio) and according to a benefit-only criterion (buying in order of greatest to smallest overall benefit) for each individual sponsor. The cumulative cost and benefit accruing as each individual item is bought are also displayed. The two lists are displayed side by side, with equal cumulative costs being displayed at the same level. Often, many items on one list are displayed in the same space that only one or two items occupy on the other list. This signifies that the larger set of items has the same cumulative cost as the smaller set, although their cumulative benefit may differ.

In general, the items will be purchased in different orders according to the two criteria, with the cost-benefit criterion preferred. Figure 3-2 represents this notion graphically. For example, the figure indicates that a fixed cost of 100 provides 50% of the maximum benefit if the benefit-only criterion is used, but the same cost provides 68% of the maximum benefit if the cost-benefit criterion is used. Figure 3-3 depicts a sample computer printout of the cost-benefit versus benefit-only display.

3.2.6 Cumulative cost display - This display yields the cumulative cost, by cost component, as each item is acquired under a variety of criteria. Any constraints

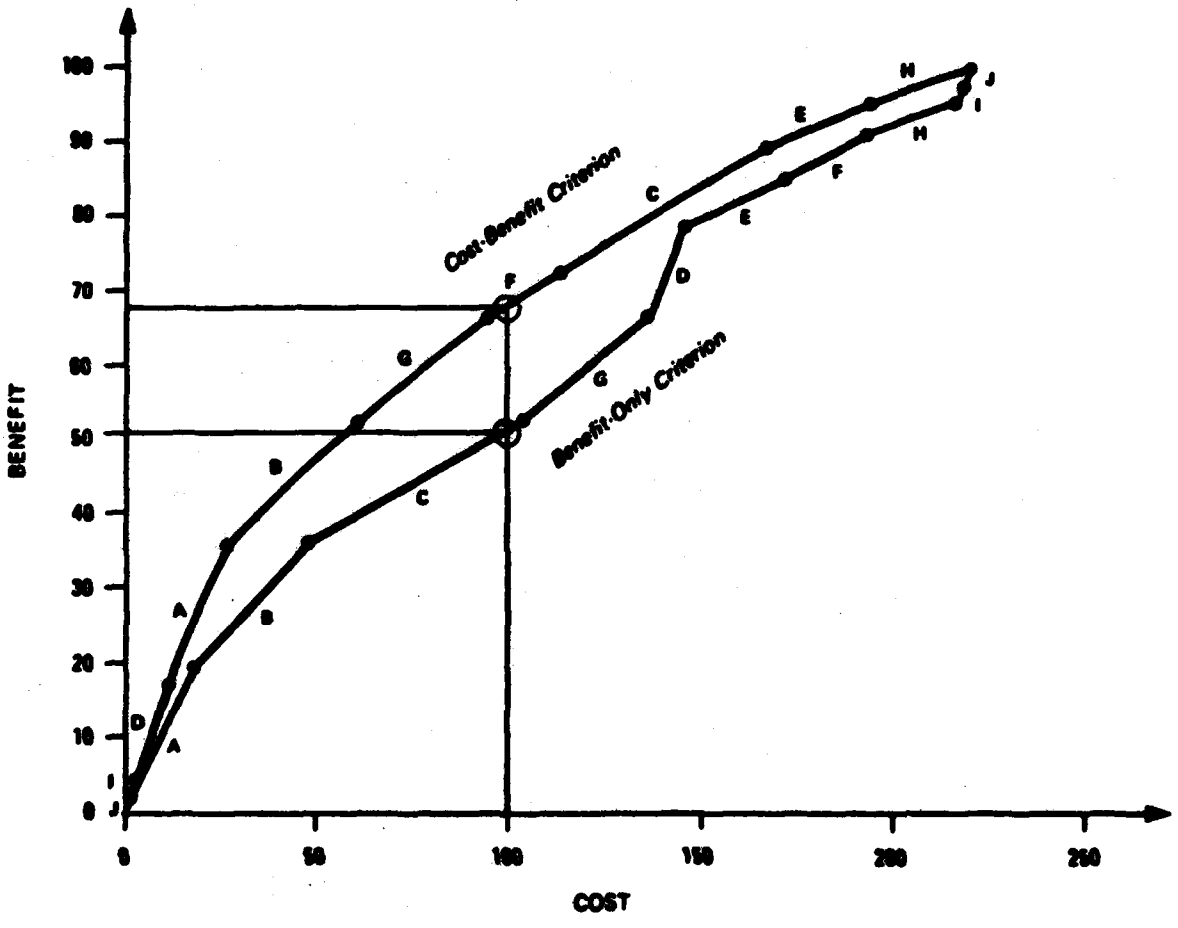


Figure 3-2
COST-BENEFIT VS. BENEFIT-ONLY CRITERIA

ORDERED BY BENEFIT	CUMULATIVE BENEFIT	CUMULATIVE COST	CUMULATIVE COST	CUMULATIVE BENEFIT	ORDERED BY COST-BENEFIT
CAREER PLACEMENT CTR	35	44.0	44.0	35	CAREER PLACEMENT CTR
			73.0	42	EXTRACURRICULAR
			125.0	53	STUDENT CENTER
			156.0	58	HOUSING GUIDE
			266.0	74	COUNSELING PROGRAM
HEALTH SERVICES	61	322.0			
COUNSELING PROGRAM	77	432.0			
STUDENT CENTER	88	484.0			
EXTRACURRICULAR	95	513.0			
HOUSING GUIDE	100	544.0	544.0	100	HEALTH SERVICES

PLEASE RETURN CARRIAGE TO CONTINUE

Figure 3-3
COST-BENEFIT VS. BENEFIT-ONLY DISPLAY

placed on any of the component costs (as well as on the total cost) can be invoked at any stage. Figure 3-4 depicts a sample display.

	OVERALL COSTS ITEM	FY80	FY81	FY82	FY83	FY84	OTHER	CUMULATIVE COST FY80	FY81	FY82	FY83	FY84	OTHER
3	2)FACULTY RAISES	180.0	190.0	202.0	215.0	230.0	0	180.0	190.0	202.0	215.0	230.0	0
4	3)CAREER PLACEMNT CTR	5.0	8.0	9.0	10.0	12.0	0	185.0	198.0	211.0	225.0	242.0	0
1	2)ALUMNI SURVEY	5.0	.0	.0	.0	.0	0	190.0	198.0	211.0	225.0	242.0	0
2	4)MAINT & RENOVATION	40.0	45.0	50.0	55.0	60.0	0	230.0	243.0	261.0	280.0	302.0	0
3	1)INTERVIEW & HIRING	15.0	19.0	21.0	23.0	22.0	0	245.0	262.0	282.0	303.0	324.0	0
4	5)EXTRACURRICULAR	3.0	6.0	6.0	7.0	7.0	0	248.0	268.0	288.0	310.0	331.0	0
2	1)LAB FACILITIES	50.0	50.0	50.0	60.0	60.0	0	298.0	318.0	338.0	370.0	391.0	0
5	2)FEDERAL RELATIONS	15.0	16.0	18.0	19.0	21.0	0	313.0	334.0	356.0	389.0	412.0	0
4	1)STUDENT CENTER	11.0	14.0	10.0	9.0	8.0	0	324.0	348.0	366.0	398.0	420.0	0
5	1)ALUMNI ASSOCIATION	4.0	5.0	5.0	6.0	6.0	0	328.0	353.0	371.0	404.0	426.0	0
4	4)HOUSING GUIDE	18.0	3.0	3.0	3.0	4.0	0	346.0	356.0	374.0	407.0	430.0	0
2	5)INVESTMENT AID	10.0	12.0	14.0	16.0	20.0	0	356.0	368.0	388.0	423.0	450.0	0
5	3)FOUNDATION SUPPORT	23.0	25.0	26.0	28.0	30.0	0	379.0	393.0	414.0	451.0	480.0	0
4	2)COUNSELING PROGRAM	19.0	20.0	22.0	24.0	25.0	0	398.0	413.0	436.0	475.0	505.0	0
3	6)BOOKS & PERIODICALS	75.0	80.0	85.0	90.0	95.0	0	473.0	493.0	521.0	565.0	600.0	0
5	5)RECRUITING	18.0	19.0	21.0	22.0	23.0	0	491.0	512.0	542.0	587.0	623.0	0
1	3)ARCHITECTURAL SURVEY	14.0	15.0	16.0	17.0	18.0	0	505.0	527.0	558.0	604.0	641.0	0
2	3)IN-HOUSE COMPUTER	280.0	300.0	25.0	27.0	28.0	0	785.0	827.0	583.0	631.0	669.0	0
4	6)HEALTH SERVICES	45.0	51.0	54.0	61.0	67.0	0	830.0	878.0	637.0	692.0	736.0	0
3	5)FACULTY OFFICE BLDG	10.0	300.0	450.0	25.0	25.0	0	840.0	1178.0	1087.0	717.0	761.0	0
1	4)EXPANSION PLANNING	20.0	21.0	23.0	24.0	25.0	0	860.0	1199.0	1110.0	741.0	786.0	0
5	4)COMMUNITY INVOLVMENT	45.0	47.0	48.0	49.0	55.0	0	905.0	1246.0	1158.0	790.0	841.0	0
3	4)BUSINESS PROGRAM	200.0	210.0	230.0	260.0	300.0	0	1105.0	1456.0	1388.0	1050.0	1141.0	0
1	1)SECRETARIAL SERVICES	15.0	17.0	19.0	21.0	23.0	0	1120.0	1473.0	1407.0	1071.0	1164.0	0
3	3)NURSING PROGRAM	310.0	340.0	370.0	400.0	450.0	0	1430.0	1813.0	1777.0	1471.0	1614.0	0
2	2)ATHLETIC COMPLEX	1000.0	4000.0	20.0	20.0	20.0	0	2430.0	5813.0	1797.0	1491.0	1634.0	0

PLEASE RETURN CARRIAGE TO CONTINUE.

Figure 3-4
OVERALL AND CUMULATIVE COST DISPLAY

4.0 RAM FUNCTIONS

RAM is designed to perform the basic functions described below. These functions are executed by two distinct subsystems: BUILDRAM and REPRAM, the former is used to construct and exercise a RAM model and the latter is used to prepare reports.

A description of the detailed logical design of the RAM functions is contained in the RAM Systems Specification, reference 1.2.5.

4.1 Functions Common to Both Subsystems

4.1.1 Maintain a library of RAM models - Store various resource allocation models, filed by their associated labels.

4.1.2 Load an existing RAM model - Display the labels of those resource allocation models stored in the model library, and permit the user to retrieve any desired model. The loaded model is referred to as the current model.

4.1.3 Save the current model - Permit the user to add the current model to the model library, or to replace an existing model with the current model.

4.2 Functions Performed Only by the BUILDRAM Subsystem

4.2.1 Create a new RAM model - Permit the user to create an entirely new resource allocation model, which then becomes the current model. The user creates a model by specifying the organizational sponsors, items, and cost components, as described in Sections 3.1.2, 3.1.3, and 3.1.4.

4.2.2 Add new data to the current model - Permit the user to apply an entire set of item costs or item benefits to the current model.

4.2.3 Add relative sponsor weights - Permit the user to apply a new set of relative sponsor weights to the model.

4.2.4 Designate "must-buy" items - Permit the user to designate those items that must be given an absolute priority in the allocation process.

4.2.5 Build the model - Perform the calculations necessary to merge all specified elements of the model into a format from which all of the available displays can be easily transformed.

4.2.6 Revise the current model - Permit the user to make changes to the structure and content of the current model. The user may:

a. edit item benefits;

b. edit item costs;

c. change item labels;

d. add new items; and

e. delete existing items.

4.2.7 Display results of the current model - Permit the user to examine the structure and content of the current model by displaying, for all of the items proposed by any single sponsor, the following:

a. item names;

b. item benefits;

c. normalized benefits;

d. total costs;

e. cost-benefit ratios; and

f. item rankings.

The user may also obtain a display of the cost-benefit versus benefit-ordering of the item procurement for all of the items of any sponsor.

4.3 Functions Performed Only by the REPRAM Subsystem

4.3.1 Sort the items - All displays available in REPRAM are available either for the items submitted by a designated single sponsor or for all items from all sponsors. The user may sort the available displays in any of the following orders:

a. by sponsor and item number;

b. by sponsor-assigned item benefit;

c. by normalized benefit;

d. by total cost;

e. by cost-benefit ratio; or

f. by ranking.

The items may be sorted either in ascending or descending order.

4.3.2 Display results of the current model - Permit the user to examine the structure and content of the node by displaying:

a. item names;

b. item benefits;

c. normalized benefits;

d. costs (both by separate component and cumulative);

e. cost-benefit ratios; and

f. item rankings.

These may be obtained for a single sponsor or for all of the sponsors, in any specified order as described in Section 4.3.1.

4.3.3 Print listing of results - Permit the user to obtain a hard-copy printout of all of the displays described in Section 4.3.2.

4.3.4 Display and edit rationale - Permit the user to display the rationale explaining the benefit number assigned to any specific item. The rationale may also be revised, should additions or corrections be required. Inputting and editing rationale are accomplished by the same software process.